

The leukemia excess was not observed in a National Research Council mortality study of soldiers exposed to five series of tests at two sites: Nevada Test Site (PLUMBBOB) and the Pacific Proving Ground (DOE 1985b). The National Research Council reported that the number of leukemia cases in "Smoky" was greater, but the increase was considered nonsignificant when analyzed with the data from the other four tests. In 1989, however, it was discovered that the roster of the atomic veterans cohort on which the National Research Council based its 1985 study contained misclassification errors. As a result, this study is being reanalyzed, and the National Research Council anticipates publishing the new results by 1997.

M.4.4 IDAHO NATIONAL ENGINEERING LABORATORY

Surrounding Communities

Jablon et al. examined cancer mortality in populations living near nuclear facilities in the U.S., including INEL in Idaho (JAMA 1991a:1403-1408). The study compared cancer mortality from 1950-1984 in 107 counties with or near 62 nuclear facilities with cancer mortality in control counties without nuclear facilities. Cancer mortality for Bingham, Butte, and Jefferson Counties, where INEL is located, was compared with nine control counties in the same region, with similar demographic characteristics. The authors concluded that no general association was detected between residents in a county with a nuclear facility and death attributable to leukemia or any other form of cancer. The authors noted that interpretation of the study results is limited by the study's ecological approach in which the exposures of individuals are not known.

Cancer morbidity and mortality data in two additional counties near INEL, Clark and Minidoka, were reviewed by the Idaho Department of Health and Welfare (ID DHW 1991a; ID DHW 1991b). Clark County lies northeast of INEL and Minidoka County southwest of INEL. Cancer death rates were examined for the years 1950-1989 and cancer incidence rates for the years 1978-1987 to determine if any significant trends in cancer morbidity and mortality could be observed in these counties compared with the entire State. No statistically significant differences in age- and sex-adjusted death rates were observed in either county.

When cancer incidence data were considered, the overall cancer incidence rate in Clark County was higher than expected based on the State of Idaho's experience. When the Clark County data were examined by primary site, only two sites were found to be significantly higher than expected—female breast cancer (8 cases observed vs. 3.2 expected, $p=0.05$) and lip cancer (3 cases observed vs. 0.4 expected, $p=0.05$). In Minidoka County, there was no increase in overall cancer incidence rate compared with the entire State. Examination by primary sites in Minidoka County, however, showed three cancer sites were found to be increased—cancer of the stomach (20 cases observed vs. 11.6 expected, $p=0.05$), lip (23 cases observed vs. 8 expected, $p=0.01$), and uterus (40 cases observed vs. 24.2 expected, $p=0.01$). These studies also suffered from the limitations inherent in ecological studies. In addition, the authors noted that too many comparisons were made for "significant" results and that the data for Clark County, with an estimated population of 800, were too small to make meaningful analyses.

State Health Agreement Program

In 1991, INEL completed a historical dose reconstruction study to examine the impact of radioactive materials released to the environment during INEL's past operations. Subsequently, under the State Health Agreement program managed by the DOE Office of Epidemiologic Studies, a grant was awarded to the State of Idaho to convene an expert panel to review the final dose reconstruction report. The State panel evaluated the environmental transport and dose assessment models used for the dose reconstruction and recommended that additional work, involving public participation, be done to more fully examine offsite consequences (ID DHW 1993a).

Workers

No occupational epidemiologic studies have been completed at INEL to date.

Memorandum of Understanding

DOE entered into a Memorandum of Understanding with the Department of Health and Human Services to conduct health studies at DOE sites, and the Centers for Disease Control and Prevention became responsible for conducting dose reconstructions in several host States, including Idaho. Under the Memorandum of Understanding, Centers for Disease Control began a phased approach to determine the need for an expansion of the dose reconstruction work initiated earlier and reviewed by the State of Idaho. The first part, data identification retrieval, was completed in 1995. No decision about the need for additional phases of a dose reconstruction for INEL has yet been reached. NIOSH is responsible for worker studies and is currently conducting a cohort mortality study of the workforce with a projected completion date of September 1997 (IN DOE 1995e).

Epidemiologic Studies

DOE's Office of Epidemiologic Studies has implemented an epidemiologic surveillance program at INEL to monitor the health of current workers. This program will evaluate the occurrence of illness and injury in the workforce on a continuing basis and the results will be issued in annual reports. The implementation of this program will facilitate an ongoing assessment of the health and safety of INEL's workforce and will help identify emerging health issues.

Currently operational at a number of DOE sites, including production sites and R&D facilities, epidemiologic surveillance uses routinely collected health data including descriptions of illness resulting in absences lasting 5 or more consecutive workdays, disabilities, and OSHA recordable injuries and illnesses abstracted from the OSHA 200 log. These health event data, coupled with demographic data about the active workforce at the participating sites, are analyzed to evaluate whether particular occupational groups are at increased risk of disease or injury when compared with other workers at a site. As the program continues and data for an extended period of time become available, time trend analysis will become an increasingly important part of the evaluation of worker health. Monitoring the health of the workforce provides a baseline determination of the illness and injury experience of workers and a tool for monitoring the effects of changes made to improve the safety and health of workers. Noteworthy changes in the health of the workforce may indicate the need for more detailed study or increased health and safety measures to ensure adequate protection for workers.

M.4.5 PANTEX PLANT

Surrounding Communities. A June 1994 study by the Texas Cancer Registry, Texas Department of Health, showed significant increases in prostate cancer mortality among Potter County and Randall County males, and leukemia mortality among Carson County males during the period 1981-1992 (TX DOH 1994a). There were no statistically significant increases observed in site-specific cancer mortality among females during this period. For cancer incidence during the period 1986-1992, no statistically significant excesses in males were seen; however, cancer of the prostate was slightly elevated in Potter/Randall County males. Analysis of the four major cell-specific types of leukemia, showed a significant excess in the incidence of chronic lymphocytic leukemia among Potter/Randall County females. This study was conducted in Carson, Potter, and Randall Counties, which are located near Pantex. This study focused only on cancers of the breast, prostate, brain, thyroid, and leukemia, which were of specific concern to citizens in the area. Other radiation-associated cancers such as bone and lung, were not included in this study. Although prostate cancer and chronic lymphocytic leukemia have not been linked to radiation exposure, further follow-up to this study was recommended.

Workers. An epidemiologic study of Pantex workers was published by Acquavella (HP 1985a:735-746). This study compared total and cause-specific mortality for Pantex workers employed between 1951 and December 31, 1978, with expected cause-specific mortalities based on U.S. death rates. Significantly fewer deaths were observed in the workforce than would be expected based on U.S. death rates for the following causes of death: all cancers (SMR=0.72; 95 percent CI=0.64-0.81), arteriosclerotic heart disease (SMR=0.75; 95 percent CI=0.61-0.91), and digestive diseases (SMR=0.46; 95 percent CI=0.22-0.85). No specific causes of death occurred significantly more frequently than expected. Slightly elevated mortality ratios were observed for brain cancer (SMR=1.36; 95 percent CI=0.37-3.47) and leukemia (SMR=1.28; 95 percent CI=0.35-3.27); neither excess was statistically significant. The four deaths from brain cancer all occurred among those who had worked at the plant less than 5 years. The four deaths from leukemia occurred with equal frequency among those who had worked at the plant a short time and those who had worked more than 15 years.

Memorandum of Understanding. A follow-up of the 1985 mortality study of the Pantex workforce is planned. The update will be conducted by NIOSH as part of a research program funded by DOE under a Memorandum of Understanding with the Department of Health and Human Services. The followup study is scheduled to commence either in late 1996 or early 1997. In addition, female workers at Pantex will be included in a NIOSH funded multisite study of mortality among female nuclear weapons workers.

Epidemiologic Surveillance. DOE's Office of Epidemiologic Studies' Epidemiologic Surveillance Program was implemented at Pantex in 1993 in order to monitor the health of current workers. This program evaluates the occurrence of illness and injury in the workforce on a continuing basis and issues the results of the ongoing surveillance in annual reports. The program facilitates an ongoing assessment of the health and safety of the site's workforce and helps to identify any emerging health issues in a timely manner. Monthly data collection began on January 1, 1994, and the results of the first complete year of epidemiologic surveillance will be presented to workers and other site stakeholder groups in spring 1996.

Currently operational at a number of DOE sites, including production sites and R&D laboratories, epidemiologic surveillance makes use of routinely collected health data including descriptions of illness resulting in absences lasting five or more consecutive workdays, disabilities, and OSHA recordable injuries and illnesses abstracted from the OSHA 200 log. These health event data coupled with demographic data about the active workforce at the participating sites, are analyzed to evaluate whether particular occupational groups are at increased risk of disease or injury when compared with other workers at a site. As the program continues and data become available for an extended period of time, trend analysis will become an increasingly important part of the evaluation of workers health. Monitoring for changes in the health of the work force provides both a baseline determination of the illness and injury experience of workers and a tool for monitoring the effects of changes made to improve the safety and health of workers. Noteworthy changes in the health of the workforce may indicate areas in need of more detailed study or increased health and safety measures to ensure adequate protection for workers.

M.4.6 OAK RIDGE RESERVATION

Surrounding Communities. The population-based National Cancer Institute mortality survey for selected nuclear facilities (NIH Publication No. 90-874; JAMA 1991a:1403-1408) examined the cancer mortality in communities near several nuclear facilities, including Anderson and Roane counties. No excess cancer mortality was observed in the population living in the exposed counties when compared to the U.S. white male population nor when compared to the population of the control counties (Blount, Bradley, Coffee, Jefferson, Hamblen, TN, and Henderson, NC), nor when time trends were assessed.

Tennessee Medical Management, Inc. used data from the Tennessee Cancer Reporting System to compare mortality and incidence data for counties near Oak Ridge, Tennessee, for the 3-year period 1988-1990 to the U.S. population (TMM 1993a). For Oak Ridge, total deaths from all causes was significantly lower than expected. For Anderson County, the observed number of deaths from uterine cancer and from cancer of

respiratory and intrathoracic organs was statistically greater than expected and the number of deaths from brain cancer, breast cancer, and all the other sites category were lower than expected for Anderson County. For Roane County, the number of deaths from cancer of the respiratory and intrathoracic organs was statistically greater than expected; the number of deaths from cancer of the digestive organs and the peritoneum, and from uterine, lip, oral cavity, and pharynx cancer was lower than expected.

Tennessee Medical Management, Inc. examined new (incident) cancer cases and identified the following statistically significant: for Anderson County, the observed numbers of cases of cancer of the prostate and of cancer of the lung and bronchus were greater than expected. Leukemia, stomach and small intestine cancers, and cancers of the colon and intestinal tract were lower than expected. For Roane County, the number of cases of cancer of the lung and bronchus was greater than expected. Non-Hodgkin's lymphoma, female breast cancer, esophageal cancer, cancer of the pancreas, and cancer in all sites were lower than expected. The only consistent excess reported for both cancer mortality and cancer incidence was for cancer of respiratory and intrathoracic organs.

Because of a concern for possible contamination of the population by mercury, the Tennessee Department of Health and Environment conducted a pilot study in 1984 (TN DHE 1984a). The study showed no difference in urine or hair mercury exposures (residence or activity in contaminated areas) compared to those with little potential exposure. Mercury levels in some soils measured as high as 2,000 parts per million. Analysis of a few soil samples showed that most of the mercury in the soil however, was inorganic, thereby lowering the probability of bioaccumulation and health effects. Examination of the long-term effects of exposure to mercury and other chemicals continues.

State Health Agreement Program. Under the State Health Agreement program managed by the DOE's Office of Epidemiologic Studies, a grant was awarded to the Tennessee Department of Health and Environment. The purpose of the grant was to determine the extent of exposure to contaminants among workers and residents of the surrounding community as a result of ORR operations and to assess the current status of health outcomes and determine their potential association with these exposures.

A dose reconstruction feasibility study began in 1992 with the contract awarded by the State of Tennessee to Chemrisk. The contractor performed extensive review of Oak Ridge documents and issued a report which concluded that sufficient information exists to reconstruct past releases and offsite doses caused by radioactive and hazardous materials. The report also concluded that doses from mercury, polychlorinated biphenyls, radioactive iodine, and radioactive cesium may have been great enough to cause harmful health effects in offsite population. Based on this information, a full dose reconstruction study was initiated in August 1994.

Other activities supported under the grant include: development of a birth defects registry; a quality improvement program for the Tennessee cancer registry; a review and evaluation of the DOE occupational medical program; and the implementation of a community participation/public information program.

Technical support to the State health department is provided by a 12 member Oak Ridge Health Agreement Steering Panel. The Health Advisory Panel provides direction and oversight to those working on health studies, ensures public input, and informs the public of activities related to the health studies. A representative of the Centers for Disease Control and Prevention's National Center for Environmental Health is a member of the advisory panel. A representative from DOE serves as an "ex-officio" member.

Workers. Between 1943 and 1985, there were 118,588 male and female individuals of all races who were ever employed in any of the Oak Ridge facilities. These included ORNL for nuclear research (also called the X-10 Facility), Y-12 under management of the Tennessee-Eastman Corporation (1943 to 1947) which produced enriched uranium by the electromagnetic separation process, Y-12 under management of Union Carbide (1948 to 1984) which fabricated and certified nuclear weapons parts, and K-25 (Oak Ridge Gaseous Diffusion Plant) which produced enriched uranium through the gaseous process. Analyses at the Oak Ridge facilities have been

carried out mostly for white males, and for specific cohorts talking into consideration time-related exposure risks.

Oak Ridge National Laboratory. The mortality experience of 8,375 white males employed at least a month between 1943 and 1972 at ORNL was compared with the U.S. white male population using SMR analyses in a 1985 paper by Checkoway, et al. (BJIM 1985a:525-533). Increases in deaths from leukemia (SMR=1.49, .16 observed; 95 percent Confidence Interval=0.31-4.38), cancer of the prostate (SMR=1.16, 14 observed, 11.9 expected), and Hodgkin's disease (SMR=1.10, 5 observed, 3.7 expected) were observed, although none were statistically significant. Dose response analyses were performed for all causes of death combined, all cancers combined, leukemia, and prostate cancer comparing exposed worker death rates with non-exposed worker death rates. Dosimetry data were available for the entire period of the study with the total population external radiation dose measuring 135 Sv. No dose response gradients were observed. Death rates were calculated for 11 different job categories by length of time in each job in an attempt to determine whether specific work environments were related to cancer and leukemia. Leukemia mortality was observed to be related to length of employment in engineering and maintenance jobs.

Follow-up of this cohort was extended through 1984 in an updated study by Wing et al. (JAMA 1991a:1397-1402). Again, death rates in the worker population were compared with those in the U.S. population. Non-statistically significant increases were noted for cancers of the pancreas (SMR=1.09, 25 observed, 95 percent CI=0.71-1.61), prostate (SMR=1.05, 26 observed, 95 percent CI=0.68-1.53), brain (SMR=1.04, 15 observed, 95 percent CI=0.58-1.72), and lymphosarcoma and/or reticulosarcoma (SMR=1.05, 9 observed, 95 percent CI=0.48-1.99). There was a significant increase in deaths from leukemia (SMR=1.63, 28 observed, 95 percent confidence, interval 1.08-2.35). The total population external radiation dose was 144 Sv. Dose response analyses performed for all causes except cancer, lung cancer, and leukemia did not demonstrate a relationship between level of external radiation and increased risk of death from these outcomes. There was a significant dose response relationship (4.94 percent per 10 milliSieverts) between cancer deaths and level of external radiation dose using models with a 20-year lag. A subgroup of workers who were monitored for internal contamination had non-statistically elevated SMRs for cancer of the prostate (SMR=1.12 10-observed), 95 percent CI=0.53-2.05 and lymphosarcoma and/or reticulosarcoma (SMR=1.65, 6 observed, 95 percent CI=0.60-3.59). The workers monitored for internal contamination had a statistically significant elevated SMR for leukemia (SMR=2.23, 16 observed, 95 percent CI=1.27-3.62).

A second publication on the above data set (Wing, et al), examined the effect of controlling for a number of possible selection and confounding factors on the risk coefficient for all cancer dose responses (AJIM 1993a:265-279). Models were adjusted for the following variables with little change in the previously reported risk coefficient: employment during the World War II era, short-term employment job category, and exposure to beryllium lead, and mercury. The authors concluded that the previously calculated dose response estimate was fairly stable when adjustments were made for a wide range of potential confounders that were not explored in the earlier study.

Y-12 Plant. Y-12 is a nuclear weapons metals fabrication plant where the radiologic exposure of greatest concern is internal exposure from the inhalation of uranium compounds. The Tennessee Eastman Corporation managed the plant from 1943 to 1947. Polednak and Frome reported a follow-up through 1974 of all 18,869 white male workers employed at Y-12 from 1943 to 1947 (JOM 1981a:169-178). The workers included those exposed to internal ("alpha") and external ("beta") radiation through the inhalation of uranium dusts, electrical workers who performed maintenance in the exposed areas, and other non-exposed workers. Individual measures of exposure were not available for any members of this cohort so exposure levels were inferred from plant areas of work and jobs. High average air levels of uranium dust were documented in departments employing chemical workers. Elevated SMRs were observed for mental, psychoneurotic, personality disorders (SMR=1.36, 33 observed, 24.2 expected), emphysema (SMR=1.16, 100 observed, 85.9 expected), diseases of the bones and organs of movement (SMR=1.22, 11 observed, 8.5 expected), lung cancer (SMR=1.09, 324 observed, 296.5 expected), and external causes of death (SMR=1.09, 623 observed, 571.8 expected). The lung cancer SMR was

greater among workers employed for 1 year or more compared with workers employed less than 1 year and was more pronounced in workers hired at the age of 45 or older (SMR=1.51; 95 percent CI 1.01-2.31). Of the workers employed after the age of 44, the SMR for lung cancer was greatest for electrical workers (SMR=1.55, 7 observed, D=1.11), alpha chemistry workers (SMR=3.02, 7 observed, D=2.27) and beta process workers (SMR=1.5, 11 observed, D=1.3).

During the early operation of Y-12, from 1942-1947, a group of male workers was exposed to phosgene gas on a chronic basis (N=694) and a smaller group of males received acute exposures (N=106) along with a small group of females (N=91) (ER 1980a:357-367; TIH 1985a:137-147). A control group of 9,280 workers who also worked at Y-12 during the same era, but who did not have phosgene exposure, was also described. All groups were followed through the end of 1978. The SMRs for the chronically-exposed group and the control group, were similar for all causes examined. There was no evidence for increased mortality from respiratory diseases in this group and the SMR for lung cancer, while elevated, was similar to the lung cancer SMR for workers in the rest of the plant. Among those with acute exposures, the SMR for respiratory diseases was elevated (SMR=2.66, 5 observed). This elevation may be related to residual lung damage from the acute phosgene exposure. It was difficult to trace the vital status of the 91 women; therefore, description of these highly exposed workers was limited to listing the frequency of their initial symptoms after exposure. As expected, nausea, vomiting and cough were the most frequently reported symptoms. Unexpectedly, the women experienced a lower frequency of pneumonitis than their male counterparts.

The portion of the Y-12 cohort employed between 1947 and 1974 was described by Checkoway et al. (AJE 1988a:255-266). This study included 6,781 white male workers first employed at Y-12 between 1947 and 1974 who were employed for at least 30 days. Mortality data were collected for the cohort through the end of 1979 and were used to perform SMR and cause specific dose-response analyses. Non-statistically significant increases were observed for all cancers (SMR=1.01, 196 observed, 95 percent CI=0.88-1.17), diseases of the blood-forming organs (SMR=1.48, 3 observed, 95 percent CI=0.31-4.38), kidney cancer (SMR=1.22, 6 observed, 95 percent CI=0.45-2.66), brain cancer (SMR=1.80, 14 observed, 95 percent CI=0.98 - 3.02), and other lymphatic cancers (SMR=1.86, 9 observed, 95 percent CI=0.85-3.53). A statistically significant increase in deaths from lung cancer (SMR=1.36, 89 observed; 95 percent CI=1.09-1.67) was observed compared with the U.S. lung cancer rates, but not with Tennessee lung cancer rates (SMR=1.18, 95 percent CI=0.95-1.45). Dose-response analyses for lung cancer and internal alpha radiation dose and external gamma radiation dose did not reveal a positive relationship for a 0-year or 10-year lag. Examination of lung cancer rates distributed across both internal and external dose categories suggested a dose-response with external radiation dose among individuals who had 5 or more rems of internal dose. Brain cancer was not related to the level of internal or external radiation dose.

The Y-12 cohort studied by Checkoway was updated through the end of 1990 by Loomis and Wolf and included African-American and white female workers (AJIM 1996a:131-141). The dose-response analyses were not included in the update; therefore, only SMR analyses are reported. For all workers examined as a group, non-statistically significant elevations were observed for cancer of the pancreas (SMR=1.36, 34 observed, 95 percent CI=0.94-1.90), skin cancer (SMR)=1.07, 11 observed, 95 percent CI=0.54-1.92), breast cancer (females only, SMR=1.21, 11 observed, 95 percent CI=0.60-2.17), prostate cancer (SMR)=1.31, 36 observed, 95 percent CI=0.91-1.81), kidney cancer (SMR=1.30, 16 observed, 95 percent CI=0.74-2.11), brain cancer (SMR=1.29, 20 observed 95 percent CI=0.79-2.00), cancers of other lymphatic tissues (SMR=1.32, 22 observed, 95 percent CI=0.82-1.99) and diseases of the blood forming organs (SMR=1.23, 6 observed, 95 percent CI=0.45-2.68). The SMR for lung cancer was statistically significant (SMR=1.17, 202 observed; 95 percent CI 1.01-1.34), particularly in the white male segment of the population (SMR=1.20, 194 observed 95 percent CI=1.04-1.38). Examination of the lung cancer mortality by year of hire, latency, duration of employment and calendar year at risk indicated the excess was confined to those who were first hired before 1954 (SMR=1.27, 161 observed), and was greatest in persons employed 5 to 20 years with 10 to 30 years of follow-up. Elevated lung cancer deaths rates were first evident between 1955 and 1964 and continued to increase from 1975 to 1979, followed by a decrease in lung cancer death rates.

Between 1953 and 1963, Y-12 used mercury in a process to produce large quantities of enriched lithium. Cragle et al. studied all workers employed at Y-12 at least 5 months between January 1, 1953 and April 30, 1958 (N=5,663) (JOM 1984a:817-821). This group was categorized into workers exposed to mercury and workers not exposed to mercury based on results of urinalysis data supplied by the plant. Vital status follow-up was complete through the end of 1978, and SMRs were calculated. Compared with non-exposed workers, there were no differences in the mortality patterns for mercury exposed workers as a whole, workers with the highest mercury exposures, and workers employed more than a year in a mercury process. The authors acknowledge that mortality is not the optimal end point to assess health effects related to mercury exposure.

The mercury workers were involved in a clinical study by Albers et al. who examined 502 Y-12 workers, 247 of whom worked in the mercury process 20 to 35 years prior to the examination (AN 1988a:651-659). Correlations between declining neurological function and increasing exposure were identified. An exposure assessment was determined for each mercury worker during the time of employment in the mercury process. Study subjects who had at least one urinalysis equal or greater than 0.6 mg./L of mercury showed decreased strength, coordination and sensations along with increased tremor, and prevalence of Babinski and snout reflexes when compared with the 255 unexposed workers. Clinical polyneuropathy was associated with the level, of the highest exposure, but not with the duration of exposure.

K-25 Site. The K-25 Site enriched uranium beginning in 1945 using a gaseous diffusion process. There was potential exposure to uranium dust, oxidized uranium compounds, uranium hexafluoride, and a number of chemical compounds used in the process. In later years of operation, the gas centrifuge process was used to enrich uranium. No analyses of death rates for this population have been published; however, health effects have been studied.

Powdered nickel was used at K-25 in the production of the barrier material used to separate and enrich uranium. Workers who fabricated the barrier material were exposed to nickel powder through inhalation. Cragle et al. updated an earlier study by Godbold et al. of 814 workers who were employed in the manufacture of barrier material between 1948 and 1953 (JOM 1979a:799-806); (IARC 1984a:57-63). A comparison group of white males employed at K-25 sometime between 1948 and 1953 (N=7,552) was also selected. The SMRs in the barrier group were similar to those in the non-barrier worker group for most non-cancer outcomes. The nickel workers were noted to have a higher rate of death from cancers of the buccal cavity and pharynx (SMR=2.92, 3 observed, 95 percent CI=0.59-8.54) than the non-nickel workers (SMR=0.23, 3 observed, 95 percent CI=0.05-0.67). When the standardized rates were directly compared, the rate of buccal cavity and pharynx cancer in the nickel workers was approximately 19 times higher than the rate in the non-nickel workers. The authors acknowledge that the number of cases is quite small and recommended additional follow-up to determine if this trend continued. There were no nasal sinus cancers observed in the worker population exposed to metallic nickel in contrast to the results of studies of workers in nickel refineries where the rates of sinus cancer related to nickel compounds are quite high.

K-25 workers employed in the gas centrifuge process were the focus of an interview study by Cragle et al. (AOEH 1992a:826-834). The study was conducted in order to determine the incidence rate for cancer and illness symptoms among workers exposed to epoxy resin and solvents prevalent in the process. A total of 263 workers determined to have worked closest and longest to the process were compared with 271 employees employed at the plant during the same time, but did not work in the centrifuge process. The centrifuge workers and the non-centrifuge workers had similar overall cancer incidence rates. However, the centrifuge workers reported five incident bladder cancers versus none reported by the non-centrifuge group. The centrifuge workers also reported significantly more rashes, dizziness, and numb or tingling limbs during employment, which are symptoms associated with high solvent exposure. One of the epoxy resins used in the early years of the process was a potential bladder carcinogen, but none of the workers with bladder cancer had jobs that required routine, hands-on work with that material. A specific causative agent for the increase in bladder cancer was not identified.

Combined-Oak Ridge Reservation Facilities. Frome et al. reported on the mortality experience of World War II workers employed at three ORR facilities between 1943 and 1947 (RR 1990a:138-152). Poisson regression analyses were used to control for potential confounders such as facility of employment, socioeconomic status, period of follow-up, and birth year. The cohort included white males employed at any ORR facility at least 30 days between the start of the operation and 1947 and were never employed at an ORR facility after 1947 (N=28,008). Elevated mortality was statistically significant for all causes (SMR=1.11, 11,671 observed, 10,537 expected; standard deviation (sd)=1), tuberculosis (SMR=1.37, 108 observed, 78 expected; sd=10.2), mental, psychoneurotic, and personality disorders (SMR=1.60, 81 observed, 50 expected; sd=10.2), cerebrovascular disease (SMR=1.11, 833 observed, 753 expected; sd=3.9), diseases of the respiratory system (SMR=1.25, 792 observed, 634 expected; sd=4.4), emphysema (SMR=1.24, 209 observed, 168 expected; sd=8.4), all accidents (SMR=1.28, 694 observed, 542 expected, sd=3.8), and motor vehicle accidents (SMR=1.44, 339 observed, 235 expected; sd=5.5). The only elevated site specific cancer that was statistically significant was lung cancer (SMR=1.27, 850 observed, 667 expected, sd=4.4, $p<0.01$). A surrogate for radiation exposure based on a workers job and department was used to indicate the probability of exposure. This surrogate for actual radiation exposure was not associated with increased rates of cancer.

Carpenter investigated earlier reports of an association between brain cancer and employment at Y-12 by conducting a case-control study of workers employed between 1943 and 1977 at ORNL or Y-12 (JOM 1987a:601-604). Cases consisted of 72 white males and 17 white females with brain cancer. Four controls were selected for each case matched on age, sex, cohort, year of birth, and year of hire. Analyses with respect to internal and external radiation exposures indicated no association with brain cancer. Two companion papers were also published from this case-control study, one examined relationships between brain cancer and chemical exposures, and the other examined non-occupational risk factors (AJIM 1988a:351-362); (AJPH 1987a:1180-1182). No statistically significant association between the use of 26 chemicals evaluated and the risk of brain cancer was observed. The chemicals evaluated included those encountered in welding fumes, beryllium, mercury, 4,4-methylene bis(2-chloroaniline) or MOCA, cutting oils, thorium, methylene chloride, and other solvents. Excess brain cancer was observed among individuals employed for more than 20 years (odds ratio=7.0, 9 cases; 95 percent CI 1.2-41.1). Analysis of 82 cases with complete medical records revealed an association with a previous diagnosis of epilepsy (odds ratio=5.7, 4 cases; 95 percent CI=1.0-32.1) recorded for pre-employment and health status follow-up.

Causes of death among white male welders (N=1,059) employed between 1943 and 1973 at Y-12, the K-25 Site, and ORNL were studied by Polednak (AEH 1981a:235-242). Based on deaths reported through 1974, mortality from all causes for welders was slightly lower than that expected based on death rates for U.S. white males (SMR=0.87, 173 observed, 199 expected, 95 percent CI=0.75-1.01). Non-statistically significant decreases in mortality were also observed for all cancers (SMR=0.88, 32 observed, 36.57 expected, 95 percent CI=0.60-1.23), especially digestive cancer (SMR=0.49, 5 observed, 10.3 expected, 95 percent CI=0.16-1.14); diseases of the circulatory system (SMR=0.74, 72 observed, 97.51 expected, 95 percent CI=0.58-0.94); diseases of the digestive system (SMR=0.76, 9 observed, 11.86 expected 95 percent CI=0.35-1.4), and accidents (SMR=0.89, 16 observed, 17.86 expected, 95 percent CI=0.51-1.44). Non-statistically significant increases were noted for lung cancer (SMR=1.50, 17 observed, 11.37 expected, 95 percent CI=0.87-2.40); diseases of the respiratory system (SMR=1.33, 13 observed, 9.77 expected, 95 percent CI=0.71-2.27), especially emphysema (SMR=2.21, 6 observed, 2.71 expected, 95 percent CI=0.81-4.82); and suicide (SMR=1.64, 10 observed, 6.09 expected; 95 percent CI=0.79 - 3.02). A subgroup of welders (N=536) exposed to nickel oxides (possible respiratory carcinogens) at K-25 were compared with welders at the other two facilities (N=523). The risk of lung cancer and other respiratory diseases did not differ between the two groups.

Combined Nuclear Sites. ORR workers have been included in several studies that have examined occupational risks across the nuclear complex, both in the United States and internationally. These combined studies have been undertaken in an attempt to increase the statistical power of the studies to detect the effects of low-level chronic radiation exposure.

Y-12 workers were included in a lung cancer case-control study of workers from the Fernald Feed Materials and Production Center cohort and the Mallinckrodt Chemical Works cohort. Dupree et al. conducted a nested case-control study of lung cancer (N=787) to investigate the relationship between lung cancer and uranium dust exposure (Epidemiology 1995a:370-375). Eligible cases were employed at least 183 days in any of the facilities and died before January 1, 1983, with lung cancer listed anywhere on the death certificate. Inclusion of deaths through 1982 allowed over 30 years of observation at each facility. One control was matched to each case on facility, race, gender, and birth and hire dates within three years. Data collected on all study members included smoking history, first pay code (a surrogate for socioeconomic status), complete work histories and occupational radiation monitoring records. Annual radiation lung dose from deposited uranium was estimated for each study member. Annual external whole body doses from gamma radiation were determined for workers who had personal monitoring data available. Potential confounders considered in the analysis were smoking (ever/never used tobacco) and pay code (monthly/non-monthly). With a 10-year lag, cumulative lung doses ranged from 1 to 137 centigrays (cGy) for cases and from 0 to .80 cGy for controls. The odds ratios for lung cancer mortality for seven cumulative internal dose groups did not demonstrate increasing risk with increasing dose. An odds ratio of 2.0 was estimated for those exposed to 25 cGy or more, but the 95 percent confidence interval of 0.20 to 20 showed great uncertainty in the estimate. There was a suggestion of an exposure effect for workers hired at age 45 years or older.

A combined site mortality study included workers from ORNL, the Hanford Site and the Rocky Flats Plant (RR 1993a:408-421). Earlier analyses of these cohorts by Gilbert et al. indicated that risk estimates calculated through extrapolation from high-dose data to low-dose data did not seriously underestimate risks of exposure to low-dose radiation (AJE 1990a:917-927; RR 1989a:19-35). The updated analyses were performed in order to determine whether the extrapolated risks represented an over-estimation of the true risk at low doses. The study population consisted of white males employed at one of the three facilities for at least six months and monitored for external radiation. The Hanford population also included females and non-white workers. The total population dose was 1,237 Sv. Analyses included trend tests for site specific cancer deaths and several broad non-cancer categories. Statistically significant trends were noted for cancer of the esophagus, cancer of the larynx, and Hodgkin's disease. These cancers were not related to radiation exposure levels in previously published studies. Excess relative risk models were calculated for the combined DOE populations and for each DOE site separately. Without exception, all risk estimates included the possibility of zero risk (that is, the confidence interval for the risk coefficient went from below zero to above zero). There was evidence of an increase in the excess relative risk for cancer with increasing age in the Hanford and ORNL population; both populations showed significant correlations of all cancer with radiation dose among those 75 years and older.

An international effort to pool data from populations exposed to external radiation included the ORNL population in addition to other radiation worker populations in the United States, Canada, and Britain (RR 1995a:117-132). The cohort comprised 95,673 workers (85.4 percent men) employed 6 months or longer and the population dose was 3,843.2 Sv. There was no evidence of an association between radiation dose and mortality from all causes or from all cancers. There was a significant dose-response relationship with leukemia, excluding chronic lymphocytic leukemia (excess relative risk=2.18 per SV, 90 percent CI=0.1-5.7) and multiple melanoma (excess relative risk not computed; 44 observed). The study results do not suggest that current radiation risk estimates for cancer at low levels of exposure are appreciable in error.

Memorandum of Understanding. The Department entered into a Memorandum of Understanding with the Department of Health and Human Services to conduct health studies at DOE sites. NIOSH is responsible for the conduct or management of worker studies.

The following studies at the ORR are managed by NIOSH with funding from DOE: a study of multiple myeloma among workers at the K-25 Plant at Oak Ridge (expected completion date 1996); a multisite study to assess the potential association between paternal exposure to ionizing radiation and the risk of leukemia in offspring of exposed male workers; a study of neurologic health outcomes in workers exposed to high levels of mercury between 1953 and 1963; studies of mortality among Oak Ridge workers; a multisite study of mortality

among female nuclear workers; a multi-site exposure assessment of hazardous waste/cleanup workers; a chronic beryllium disease study; and a multi-site study of heat stress and performance among carpenters.

M.4.7 SAVANNAH RIVER SITE

The Savannah River Site, established in 1953 in Aiken, SC, produced Pu, tritium, and other nuclear materials. There are reports that millions of curies of tritium have been released over the years both in plant exhaust plumes and in surface and groundwater streams (ED 1982a:135-152).

Surrounding Communities. In 1984, Sauer and Associates examined mortality rates in Georgia and South Carolina by distance from the Savannah River Plant (now known as the SRS) (SR duPont 1984b). Rates for areas near the plant were compared with U.S. rates and with rates for counties located more than 50 miles away. Breast cancer, respiratory cancer, leukemia, thyroid cancer, bone cancer, malignant melanoma of the skin, non-respiratory cancer, congenital anomalies or birth defects, early infancy death rates, stroke, or cardiovascular disease in the populations living near the plant did not show any excess risk compared with the reference populations.

State Health Agreement Program. Under the State Health Agreement program managed by the DOE Office of Epidemiologic Studies, a grant was awarded to the Medical University of South Carolina in 1991 to develop the Savannah River Region Health Information System. The purpose of the Savannah River Region Health Information System database was to assess the health of populations surrounding SRS by tracking cancer rates and, birth defect rates in the area. Information from the registry is available to public and private health care providers for use in evaluating cancer control efforts. A steering committee provides advice to the Savannah River Region Health Information System and communicates public concerns to Savannah River Region Health Information System. It consists of 12-community members and persons with technical expertise representing South Carolina and Georgia. The meetings are open to the public.

Workers. A descriptive mortality study was conducted that included 9,860 white male workers who had been employed at least 90 days at the Savannah River Plant between 1952 and the end of 1974 (AJIM 1988b:370-401). Vital status was followed through the end of 1980 and mortality was compared with the U.S. population. SMRs were computed separately for hourly and salaried employees. For hourly employees non-statistically significant increases were seen for cancer of the rectum (SMR=1.09, 5 observed, 95 percent CI=0.35-2.54), cancer of the pancreas (SMR=1.08, 10 observed, 95 percent CI=0.59-2.18), leukemia and aleukemia (SMR=1.63, 13 observed, 95 percent CI=0.87-2.80), other lymphatic tissue (SMR=1.06, 5 observed, 95 percent CI=0.34-2.48), benign neoplasms (SMR=1.33, 4 observed, 95 percent CI=0.36-3.40), and motor vehicle accidents (SMR=1.10, 63 observed, 95 percent CI=0.84-1.4). Salaried employees exhibited non-statistically significant increases in cancer of the liver (SMR=1.84, 3 observed, 95 percent CI=0.38-5.38), cancer of the prostate (SMR=1.35, 5 observed, 95 percent CI=0.44-3.16), cancer of the bladder-(SMR=1.87, 4 observed, 95 percent CI=0.51 4.79), brain cancer (SMR=1.06, 4,observed, 95 percent CI=0.29-2.72), leukemia and aleukemia (SMR=1.05, 4 observed, 95 percent CI=0.29-2.69), and other lymphatic tissue (SMR=1.23, 3 observed, 95 percent CI=0.26-3.61). No trends between increasing duration of employment and SMRs were observed. A statistically significant excess of leukemia deaths was observed for hourly workers employed at least 5, but less than 15 years (SMR=2.75, 6 observed, 95 percent CI=1.01-5.99). Review of the plant records and job duties of the workers who died from leukemia indicated that two of the cases had potential routine exposure to solvents, four had potential occasional exposure to solvents and one had potential for minimal exposure. Benzene, a known carcinogen was reportedly not used at the plant.

Epidemiologic Studies. The Department's Office of Epidemiologic Studies has implemented an Epidemiologic Surveillance Program at SRS to monitor the health of current workers. This program will evaluate the occurrence of illness and injury in the workforce on a continuing basis and the results will be issued in annual reports. The implementation of this program will facilitate an ongoing assessment of the health and safety of SRS's workforce and will help identify emerging health issues.